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TESTS OF LOSS OF HEAD IN STRAINERS, ORIFICES AND SAND

By Langdon Pearse

The data given in this paper are derived from experiments made by Mr. W. W. DeBerard and the author in 1908, during filtration investigations for the Peoples Water Company of Oakland, California.

The tests of the loss of head in strainers used in rapid filters and in small orifices were made in an apparatus (fig. 1) consisting of a redwood box, 18 by 18 inches square and 12 inches deep, inside measurements, a set of 4 inch pipe and flanges arranged as shown, a three-quarter inch regulating valve, a level rod fitted with a hook gauge, a gauge glass, rubber connecting tube and a collecting bucket, holding about 45 pounds of water. Platform scales completed the equipment. The rig was set up in the testing station, the box being supported on wooden legs, while the pail was set on a sink with a drain to the sewer. At first the supply was taken from coagulated water, but the presence of floc, even though fine screen was used, quickly forced a change to clear water.

The method of operation was as follows: the orifice plate to be tested was set in position between the two flanges of the 2 inch flange union, with a rubber gasket on each side. The valve was then opened and the water allowed to flow through, the joint being carefully inspected for leaks. All the bolts in the flanges were thoroughly tightened before complete submergence. Water was then turned into the box, and when the water had risen above the flange union all the air underneath was sucked out with a small rubber tube. The space underneath was always tested for air after each run at a given head, but little air was found, after the first removal. The water was then allowed to rise in the standpipe to the desired head, and when the level in the box had attained a constant elevation, the hook gauge was set. At first the valve was set, the readings of the head being taken every ten seconds on the water column. It was found better to maintain a constant level, which was readily accom-

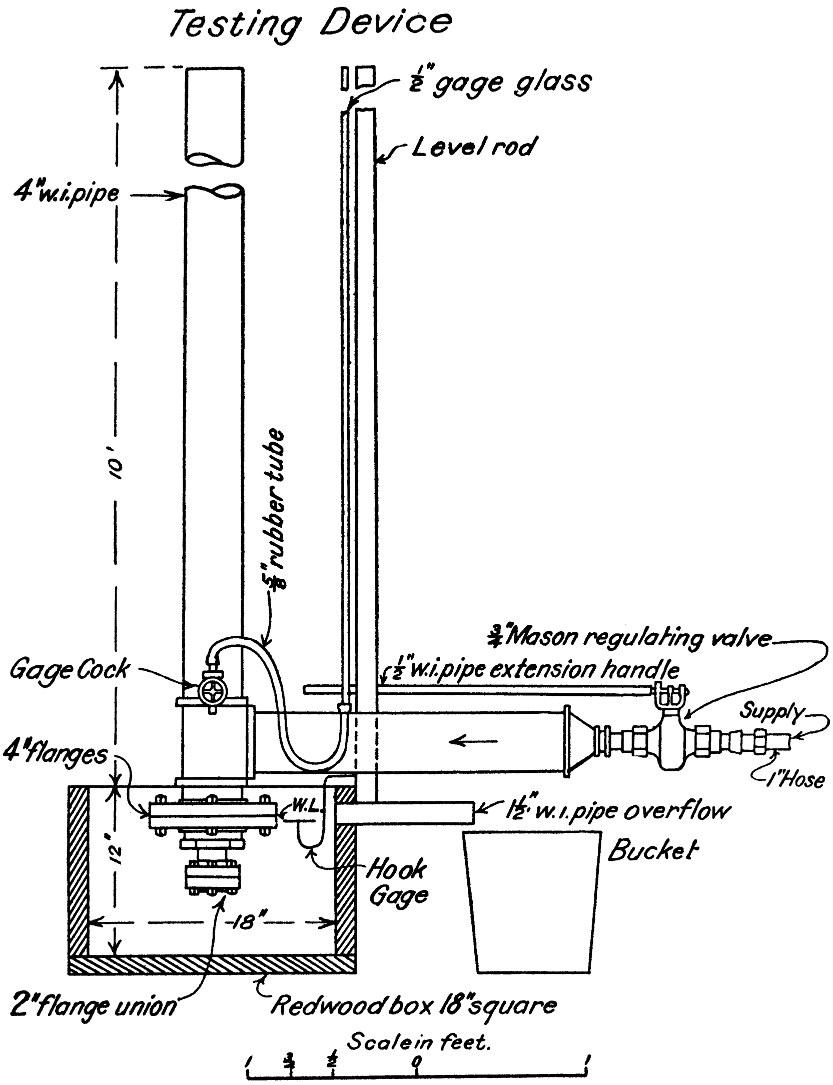

Testing Device
½" gage glass
Level rod
4" w.i. pipe
10'
⅝" rubber tube
¾" Mason regulating valve
½" w.i. pipe extension handle
Gage Cock
Supply
4" flanges
1" Hose
W.L.
1½" w.i. pipe overflow
12"
Hook Gage
Bucket
18"
2" flange union
Redwood box 18" square
Scale in feet.
1 ¾ ½ ¼ 0 1

FIG. 1

plished by the aid of the extension handle on the regulation valve. When the apparatus had been running smoothly for a few minutes, usually two and not over five, the bucket was swung under the overflow and allowed to fill for an even number of minutes. It was then removed, weighed on scales, and then emptied. The weight of a cubic foot of water was taken at 62.4 pounds. No correction was made for temperature.

TABLE 1

Tests of orifices

ORIFICE NUMBER	NOMINAL DIMENSION		ACTUAL DIMENSION		RATIO	AVERAGE VALUE C	RANGE OF HEAD FEET	NUMBER OF TESTS AVERAGED
	d	t	d	t	$\frac{d}{t}$			
	in.	*in.*	*in.*	*in.*				
54	$\frac{1}{4}$	$\frac{1}{16}$	0.2486	0.0601	4.138	0.624	1.25- 9.91	13
53	$\frac{3}{16}$	$\frac{1}{16}$	0.189	0.0601	3.15	0.612	2.0 -10.0	13
52	$\frac{5}{32}$	$\frac{1}{16}$	0.1569	0.0601	2.61	0.622	1.20-10.0	11
51	$\frac{1}{8}$	$\frac{1}{16}$	0.1266	0.0601	2.11	0.685	1.99-10.0	10
50	$\frac{3}{32}$	$\frac{1}{16}$	0.093	0.0601	1.547	0.68	1.20-10.0	10
49	$\frac{1}{16}$	$\frac{1}{16}$	0.0619	0.0601	1.03	0.741*†	1.99-10.0	9
48	$\frac{1}{4}$	$\frac{5}{64}$	0.25	0.0801	3.01	0.612	1.92- 9.8	11
47	$\frac{3}{16}$	$\frac{5}{64}$	0.1904	0.0801	2.38	0.612	1.99- 9.92	5
46	$\frac{5}{32}$	$\frac{5}{64}$	0.1572	0.0801	1.96	0.678	2.0 -10.0	5
45	$\frac{1}{8}$	$\frac{5}{64}$	0.1272	0.0801	1.59	0.718	2.0 -10.0	5
44	$\frac{3}{32}$	$\frac{5}{64}$	0.0935	0.0801	1.17	0.739	2.0 -10.0	5
43	$\frac{1}{16}$	$\frac{5}{64}$	0.0609	0.0801	0.761	0.852	2.0 -10.0	5

* Averaged from 2 sets, $C = 0.689$ and $C = 0.794$.

† Averaged from 2 sets, $C = 0.780$ and $C = 0.640$.

As all the tests were made with the orifices or strainers submerged, the head "h" in feet, given in the tables, is the actual head lost in passing through the orifice or strainer, and is measured by the difference of level of the water inside the standpipe and inside the redwood box.

In the tables the following abbreviations are used:

d = diameter of orifice
t = thickness of plate
C = coefficient of discharge

Table 1 shows a summary of the tests of orifices. These orifices were holes drilled through steel plates of the thickness noted, all burrs being carefully removed. The results indicate a coefficient of discharge ranging from 0.62 where the ratio of $\frac{d}{t} = 4.1$ up to 0.85 with a ration of $\frac{d}{t} = 0.76$. With a very few exceptions the coefficient "C" varied but little for the range of head tried on any one orifice. On orifices 50 and 49, two independent sets of observations gave results somewhat at variance as noted.

TABLE 2

Test of Wilson strainer. Used at Binghamton, New York

Total area slots = 1.101 square inches = 0.00764 square foot. $Q = 0.0613\ C\sqrt{h}$.

Area w.i. pipe = 0.864 square inch = 0.006 square foot. $Q = 0.0481\ C\sqrt{h}$.

POUNDS PER MINUTE	CUBIC FEET PER SECOND	HEAD IN FEET	$\sqrt{h}$	VALUE OF C	
				Area Slots	Area Pipe
112.6	0.0301	2.173	1.474	0.333	0.425
150.2	0.0401	3.96	1.99	0.329	0.419
200.5	0.0536	7.18	2.68	0.326	0.416
Average				0.329	0.420

TABLE 3

Test of Denver strainer. Used by Denver Union Water Company, Denver, Colorado

Copper plate 2⅝ inches diameter. 0.023 inch thick contains 1098 effective holes each 0.032 inch diameter.

Total area holes = 1098 (0.000805) = 8.885 square inches = 0.00614 square foot.

Ratio $\frac{d}{t} = \frac{0.032}{0.023} = 1.39$. $Q = 0.0492\ C\sqrt{h}$.

GALLONS PER MINUTE	CUBIC FEET PER SECOND	HEAD IN FEET	$\sqrt{h}$	VALUE OF C		REMARKS
				As obtained	Corrected	
17.5	0.0373	1.10	1.049	0.723	0.723	
22.1	0.0471	1.76	1.326	0.722	0.735	20 holes plugged
26.1	0.0557	2.42	1.555	0.728	0.736	18 holes plugged
Average				0.724	0.731	

TABLE 4

Test of Greer strainer

Total area slots, 0.4844 square inch = 0.003363 square foot. $Q = C \times 0.0269 \sqrt{h}$.

Area throat, 0.132 square inch = 0.000917 square foot. $Q = C \times 0.007354 \sqrt{h}$.

POUNDS PER MINUTE	Q CUBIC FEET PER SECOND	h	$\sqrt{h}$	VALUE OF C		REMARKS
				Throat	Slots	
19.05	0.00509	1.074	1.036	0.6685	0.182	2 runs
28.02	0.00749	2.067	1.438	0.708	0.193	3 runs
40.00	0.01069	4.08	2.02	0.719	0.196	2 runs
48.88	0.01306	6.11	2.47	0.718	0.196	4 runs
55.22	0.01476	7.654	2.769	0.725	0.1977	4 runs
Average				0.7077	0.1929	

TABLE 5

Test of Little Falls strainer. Used at Little Falls, New York

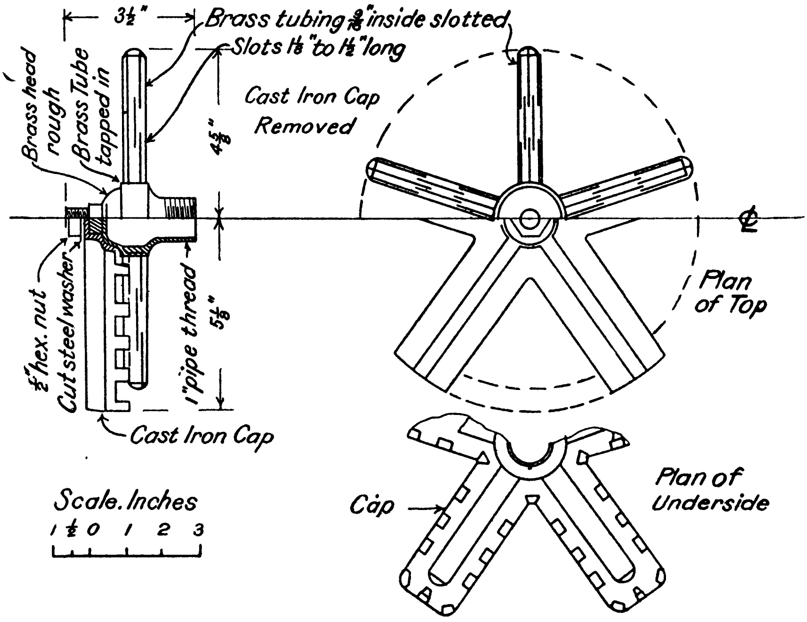
Total area of holes, 0.1161 square inch = 0.000806 square foot. $Q = C \times 0.006464 \sqrt{h}$.

Area inlet pipe, 0.1135 square inch = 0.000788 square foot. $Q = C \times 0.00632 \sqrt{h}$.

POUNDS PER MINUTE	Q CUBIC FEET PER SECOND	H HEAD IN FEET	$\sqrt{h}$	VALUE OF C		REMARKS
				Inlet	Holes	
12.05	0.00324	1.143	1.07	0.480	0.469	3 runs
16.00	0.00427	1.97	1.404	0.481	0.471	3 runs
23.42	0.00626	4.12	2.03	0.488	0.477	3 runs
23.09	0.0075	5.95	2.44	0.487	0.476	3 runs
32.60	0.00869	8.03	2.832	0.486	0.475	3 runs
36.38	0.00972	9.87	3.14	0.49	0.479	3 runs
Average				0.485	0.4745	

Tables 2, 3, 4 and 5 give the data obtained on the strainers of the Wilson, Denver, Greer and Little Falls types. The dimensions of the strainers tested are given in figures 2, 3, 4 and 5. The resulting C is computed on both the supply pipe and the openings for strainers of the Wilson, Greer and Little Falls type.

The Columbus, Ohio, strainer plate is shown on figure 6. The average coefficient C was 0.736 for heads varying from 1 to 10 feet. This is an average of 28 observations.



Data on Slots

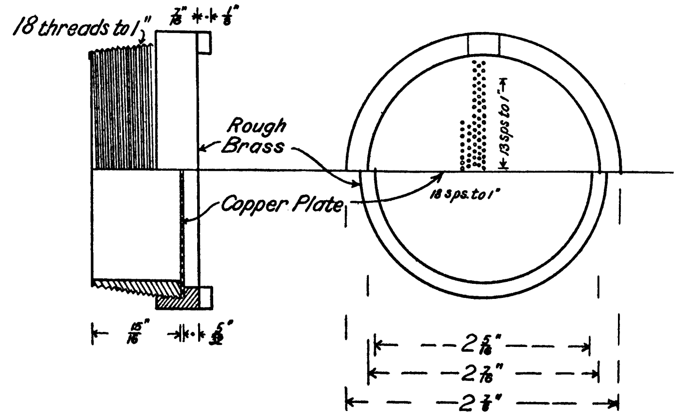
Length per pipe in.	Width in.	Area sq. in.
$25\frac{3}{16}$	0.009	0.23
24	0.009	0.216
{$16\frac{3}{16}$	0.009	0.146
6	0.013	0.078
$23\frac{1}{4}$	0.009	0.209
$24\frac{5}{8}$	0.009	0.222

Weight of Materials
Cast Iron Cap, Nut, Washer 4 lb. 6 oz.
Brass Head and Tubes 1 lb.

FIG. 2. WILSON STRAINER

The tests of loss of head in the strainers and sand were made in the working experimental filters each 4 feet square inside dimensions.

In filter 2, the underdrain was of the combined type designed to use air and water alternately through a single pipe system similar to the one installed at Harrisburg, Pennsylvania. This underdrain consisted of a 3 inch galvanized-iron pipe header with eight lateral pipes, $1\frac{1}{4}$ inches diameter, spaced 6 inches center to center. On the under side of the pipes are drilled $\frac{7}{32}$ inch diameter holes, 3 inches center to center making eight rows of 16 holes each, a total of 128 holes, with a total area of 4.81 square inches equivalent to about 0.21 of 1 per cent of the area of the filter.



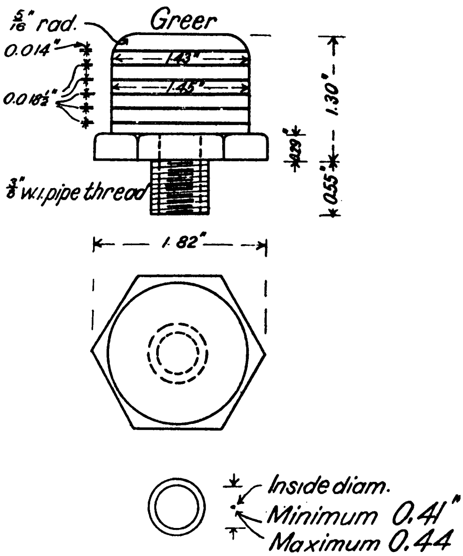
Weight of Material
Rough Brass 7 oz.
Copper Plate ½ oz.

Note.
The copper plate is 2⅝" diam. and 0.023" thick, containing 1098 effective holes 0.032 diam. Total Area = 0.884 sq. in.

FIG. 3. DENVER STRAINER

Filter 3 was designed for a high-rate wash, with water only, using a pipe system similar to the first, but with a 4 inch header and 2 inch laterals. On the under side of the pipes there are drilled eight rows of 15 holes each, approximately $\frac{5}{16}$ inch diameter. The total area of the holes is 9.204 square inches, equivalent to 0.40 of one per cent of the area of the filter. A wire screen was placed over the gravel and tied down to prevent displacement by the high velocity of the wash water.

Filter 4 has an underdrain modeled after that at Cincinnati, Ohio, except that it is built of wood instead of concrete, and the wire screens over the gravel are omitted. There are six plates, each containing 58 holes $\frac{3}{16}$ inches in diameter. The total area of the 348 holes in the plates is 9.6 square inches, equivalent to 0.42 of 1 per cent of the area of the filter. During the experiments the filter was rebuilt, using plates each containing the same number of holes as before, but $\frac{1}{8}$ inch in diameter, equivalent to 0.19 of 1 per cent of the area of the filter.



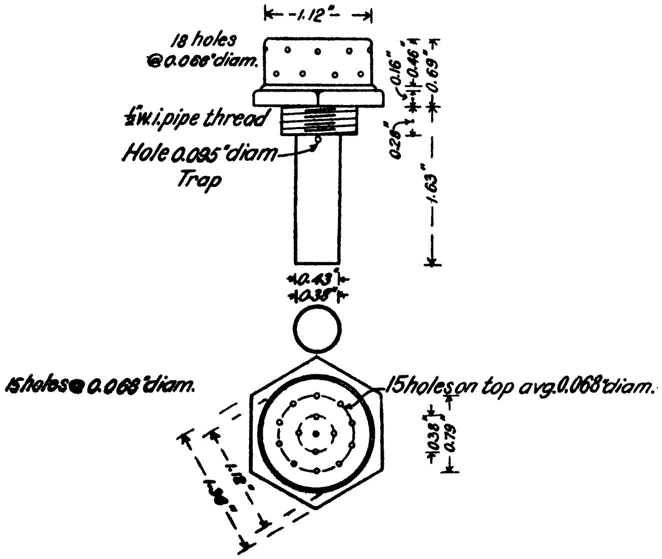
Data

Description	Diam in.	Area Sq. in.
Slots Inlet	0.41	0.4844 0.132

Material Brass
Weight 5 oz.

FIG. 4 GREER STRAINER

Little Falls

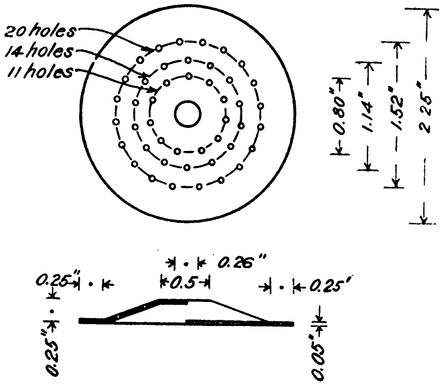


Data

Description	Diam. in.	Area Sq. in.
Inlet Pipe	0.38	0.1135
Trap Hole	0.095	0.0071
Holes 33		0.1161

Material Brass
Weight 2 oz.

FIG. 5



Holes 45 Avg. diam. 0.065 in.
Total Area 0.1493 sq. in.
Weight brass plate, yoke and bolt 2 ½ oz.

FIG. 6 COLUMBUS STRAINER

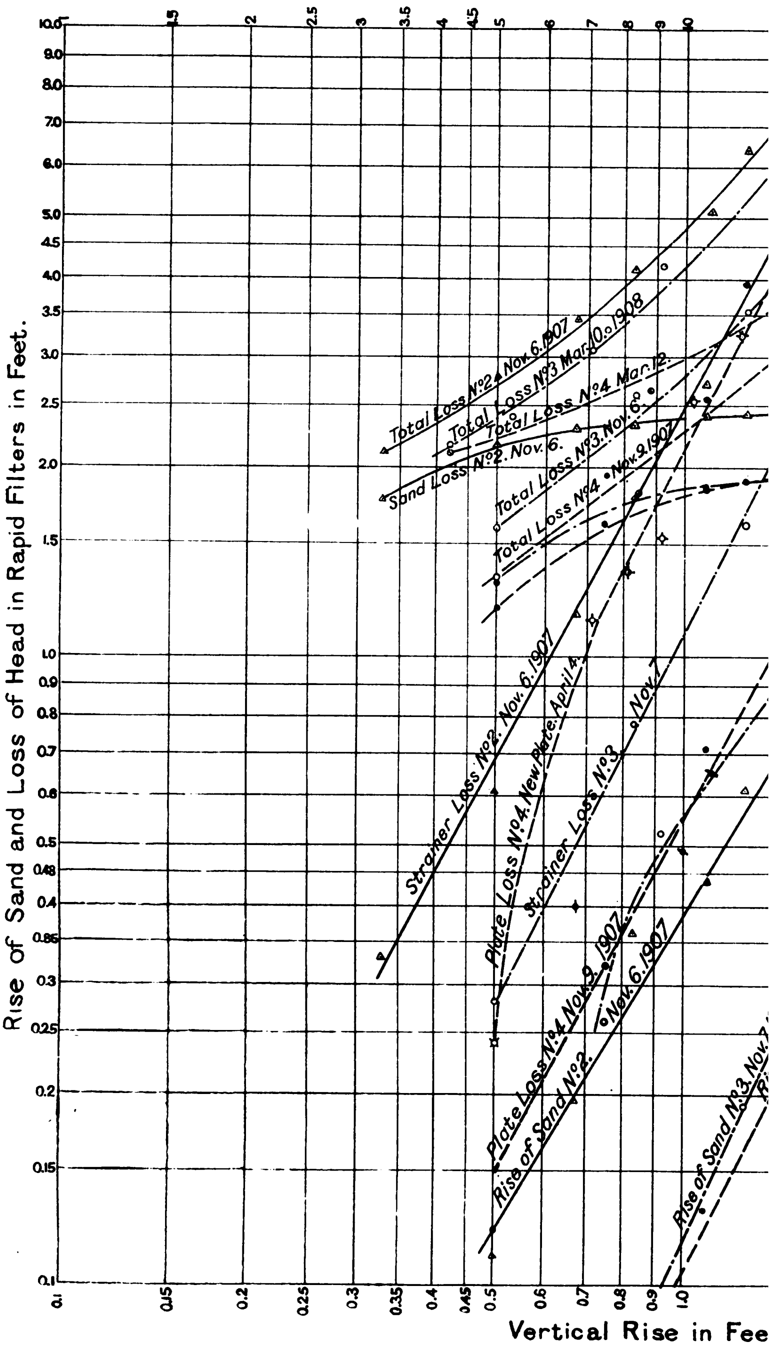
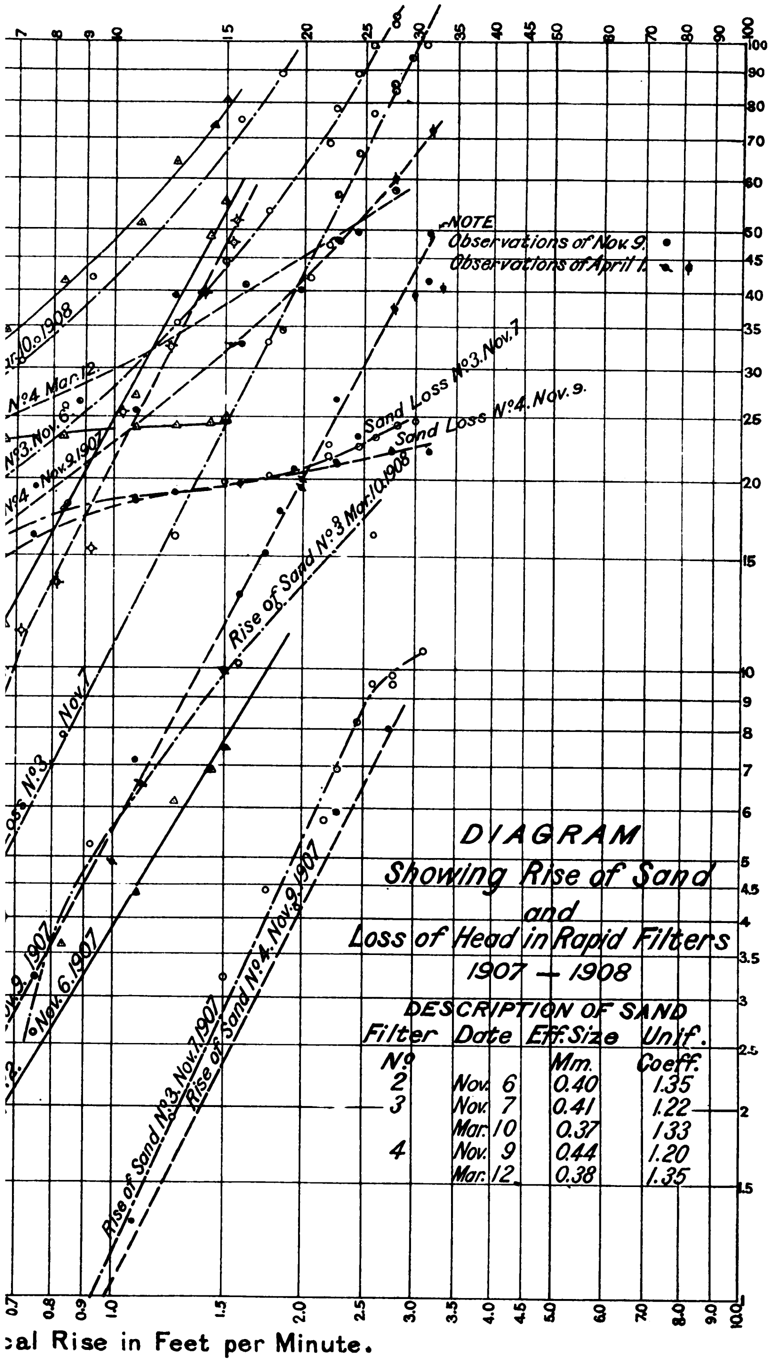


FIG. 7. RISE OF SAND AND LOSS OF HEAD FOR VARIOUS R



ad for Various Rates of Vertical Rise of Wash Water

The curves plotted in figure 7 are on a logarithmic scale. In each case for filters 2, 3 and 4 a curve is drawn showing the strainer or plate loss, the sand loss, and the total loss of head through both strainer and sand for various rates of wash water. In addition the rise of the sand is given. The analysis of the sand is noted on the diagram. In general the finer sand with a higher uniformity coefficient rose to a greater height with a given vertical rise of wash water.

The data given in this paper are not always of the highest degree of accuracy, owing to the conditions under which the experiments were made. They are, however, of value as an aid to judgment in selecting coefficients or in studying the behavior of sand filters. Further data acquired along these lines in actual plants would be of service.